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Three psychological disciplines offer approaches to an understanding of intelligence. An attempt is made to uncover the common features of the psychometric school, learning, and mental development approaches. A structural concept is selected from each psychological discipline for comparative analysis: the concept of factor from the psychometric approach; learning set from Harlow's learning approach, and schema or operation, from Piaget's developmental orientation. The concepts are found to share in two basic characteristics--situational generality and embodiment in a hierarchical organization. An attempt is made to relate consistency of inter-situational experience to a consistency in inter-situational performance. It is suggested that all approaches involve competence with respect to a class of diverse situations and that if these situations form a class, they must have some features in common. Intelligence must mean sensitivity to these common features and such sensitivity could probably be learned through the continual learning of such features presented in diverse settings.

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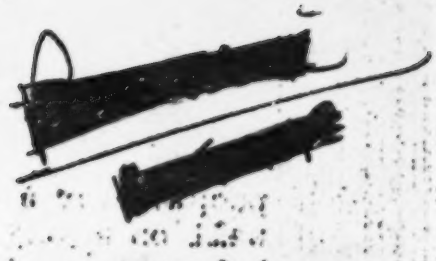

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INTELLIGENCE AND LEARNING*

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There are at least three psychological disciplines that talk about intelligence. These particular disciplines rarely talk to one another but they do have things to say about mentality. There is first of all the psychometric school. The emphasis here is upon individual differences in test reactions, on the study of the interrelationships among test performances, and on the study of factors derived from these interrelationships. The second approach to the study of intelligence is by way of learning. Here the term intelligence is not used explicitly too often, but cognitions, insights, expectations, s-r bonds, and s-s connections must have something very vital to do with intelligence. In contrast to the test, the preferred method here is the controlled experiment and the correlation of response change with situational variation. A third approach is the mental development one, where the focus is upon the child and the methodology may partake of observation, experiment, or test.

I want to avoid a focus upon the differences in the above three approaches, but rather point up some common features. Despite great variance in methodological stress and theoretical orientation, these three approaches may show some sign of communality if not convergence. Perhaps communality is the wrong word. They are, after all, not looking at the same thing but at different aspects of the same thing, so that terms like consistency or articulation might be more apt if rapprochement is desired.

What we might do then is select from each of these three approaches a structural concept. With three of these structural concepts, one from the psychometric tradition, one from the learning theory world, and one recruited from developmental ideas, there is the opportunity for comparative analysis. These three concepts then, which I have selected are: 1. the concept of a factor, from the psychometric approach, 2. learning set, from Harlow's learning approach, and 3. schema or operation, from Piaget's developmental orientation.

The first characteristic shared by these three types of cognitive structure is generality, scope. Thus, a factor is not defined in terms of performance on a single test, but is abstracted from the consistencies of

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people over a relatively wide gamut of tests. An individual tending to do well on a verbal comprehension factor would not only stand high on a vocabulary test, but also do relatively well on a general information test, on a reading test, and on a verbal reasoning test and so on.

Just as the factor is defined in terms of inter-test consistency, so a learning set is defined in terms of inter-problem consistency Most learning experiments are intra-problem in format. Thus, one presents a recurring set of conditions to the subject and the improvement in performance is attributable to learning, provided other explanatory variables are controlled, such as adaptation and fatigue effects. The rat is run through the same maze until he has mastered it according to some criterion; the at is place in the same problem box time after time until he reaches a desired level of proficiency. What Harlow (4,5) has done is disrupt this situational invariance. He gives his monkeys experience in a particular discrimination set-up. For example, the problem may be to discriminate a triangle from a circle, with the selection of the triangle rewarded by food. Then, after a certain amount of proficiency is attained, he switches the problem so that the subject must now learn to discriminate a square from an ellipse. When some learning has been attained in this situation, the problem is changed again, and then again, and yet again, for what may be hundreds of problems. It should be noted that each problem is a new one in the sense that the subject must learn anew which is the correct or rewarded stimulus, for the cues associated with the correct stimulus shift from problem to problem.

The interesting finding is that the more experience the subject has with this particular type of problem, the faster and more efficiently he is able to handle a new problem of this type. After several hundred of these problems, the monkey, for example, may approach a new discrimination with what seems to be enormous insight, getting the hang of it in one or two trials. His more unfortunate cage mate, who has not had this educational background (or is it enrichment?), i.e., who has not had the same amount and variety of experience with this kind of problem, has to resort to more exploratory trial and error behavior which extends over a relatively large number of trials. Hence the term learning how to learn is an apt discription of learning set. The subject has learned in the past how to learn the novelties of the here and now. Similar results, it should be mentioned, have been obtained with children at pre-school and kindergarten ages (3,7,9) so that learning set is by no means a restricted set, like the factor is inferred from performance on a variety of situations rather than from performance on any one type of problem. We could even test for learning set without knowing the subject's history by the degree of his success on a variety of these situations, but not from the success in any one of them. Indeed, if we were to do a factor analysis of say 20 new discrimination problems, my hunch is that a large general factor would emerge. Those with a great deal of learning set experience would tend to do well on all 20 tasks; those with limited learning set backgroupd would tend to do poorly on all 20, contributing to very high intercorrelation among problems and to the inference of a general factor. I don't think this has ever been done, but I think it's important that it be done since

it would specify a possible etiological background of a general factor.

Let's move to the developmental area. An outstanding characteristic of Piaget's notions is their trans-situational character. Indeed, this generality is a great source of their strength and predictive power. Thus, the very idea of concrete operations spans a number of different situations, employing different materials, different formats, and different methods of presentation and direction. Thus, according to Piaget if the child has attained the phase of concrete operations he should be able to handle the conservation of quantity problem. Now the ability to conserve quantity can be tested in at least two different ways, both of which are probably familiar to many of you. One way involves showing the child two regular-sized glasses filled with water. A five year old will readily admit that there is the same amount of water in both glasses. Indeed he may be quite meticulous and accurate in lining up the two levels. However, if one glass is emptied into three small tumblers, he is quite likely to say that there is more water in the remaining regular glass (because "it's longer"), than in the three tumblers. And it doesn't help if you pour the water from the tumblers back into the original glass and demonstrate the equality of amount in both regular glasses. Repeat the experiment and he will stick to his story, at least my five-year-old daughter did when I tried this the other night. And I might add that it gives one a spooky feeling to realize how little you know about the way your own child sees the world. But putting fatherly digressions aside, let's get back to the point. The point is that this conservation of quantity can be demonstrated with a quite different set of procedures. Instead of dealing with the conservation of quantity in one continuous object or medium such as water, Piaget investigated the conservation of quantity in a group of objects. Thus, if you present this hypothetical five-year-old with a set of eight egg cups and a matching set of eight eggs, there will be the admission that the quantity of the egg-cup-group is equal to the quantity of the egg-group. However, if the eggs are taken out of the egg cups and assembled in aconstricted space in front of the egg cups, the two quantities become unequal and conservation is dramatically abandoned. The egg-group, now occupying asmaller space than the egg-cup-group, is judged as smaller in quantity. Conversely, if the egg-group is spatially extended, so that it spreads out and covers a wider distance than the egg-cup group, the number of eggs is considered more than the number of egg cups. Again we see a psychological attribute, a cognitive structure, defined in terms of situational diversity. Suppose 20 different situations were devised, each tapping the conservation of quantity dimension, and these were administered to fifty 6-year-olds and fifty 8-year-olds. A factor analysis, and here I go a-hunching again, would reveal a large general factor underlying the 20 problems. A given eight-year-old would tend to pass all 20 (since he will probably be in the stage of concrete operations), while a given six-year-old will probably fail all 20 since he probably will be in the earlier intuitive phase where conservation of quantity has not been attained. Such hypothecated consistency of success and failure over all twenty problems would induce high intercorrelations among the problems, which would in turn be reflected in a general factor. Suppose again we were fortunate enough to have a complete record for each child of each of his life experiences in which two sets of objects were aligned in a one-to-one correspondence. Thus,

each time he sits sown in a classroom and the other children sit at their desks there is a one-to-one correspondence between the children-group and the desk-group. Twenty children are aligned with twenty desks a la eggs and egg cups. If he sets a table at home, he counts out four napkins and places them beside four plates, and the napkin set is aligned with the plate set. When he chooses up sides, his team is aligned man-for-man with the opposing team, so that there is a correspondence between the number in his team and the number in the opposing team. If we could chronicle all these experiences for each member of our study population, we might be able to assign a learning set score to each based on the number and variety of such conservation experiences, and most important, on the frequency with which adults or older children reinforce the idea that the number in the two corresponding sets is a constant <u>despite</u> varying spatial arrangements of the objects in each set. It may very well be that such an experiential index would correlate quite highly with the factorial score obtained from the degree of success or failure on the twenty conservation-of-quantity problems mentioned above.

Let me make the analogy to Harlow's work more explicit. In Harlow's experiments, it was suggested that a factorial score obtained from performance at a particular time on twenty fresh discrimination problems would be correlated with a learning set measure derived from the degree of experience subjects have had with this class of problem. In similar fashion, it may be that a factorial score derived from performance on a range of fresh conservation-of-quantity problems would be related to the conservation-of-quantity learning set. This learning set would be independently assessed through knowledge of the intensity, variety, and reinforcement value of successive conservation-of-quantity experiences. Of course, the chronicling of such experiences would be enormously difficult to do, from a purely practical standpoint, even ignoring the methodological and conceptual difficulties, which you can't. It would be easier to set up such procedures in a relatively controlled setting such as a laboratory or a classroom, to make them the independent variables in an experiment, or the enrichment procedure in an enrichment program. The basic idea is the devising of situations where the numerical invariance <u>between</u> two sets of objects <u>within</u> each of the two sets.

Let's return again to the question of the communalities among the concepts of factor, learning set, and schema or operation. A second communality, besides the first one of situational generality, is the idea that each of these structures is embedded in a hierarchical organization. The idea of a hierarchical organization of structures is most readily seen in the case of learning certain school subjects. Thus, knowledge of algebra, structure 1, is lower in the hierarchy than knowledge of calculus, structure 2, which is in turn lower in the hierarchy than knowledge of some higher order mathematical realm structure 3. I think there are at least two ways to look at this hierarchical idea. One way is in terms of direction of prediction. If you know that a person knows a good deal of calculus, you can predict that he knows a good deal of algebra, but the prediction from knowledge of albegra to knowledge of calculus is much more risky. Similarly, you know and you can predict that if a child can ride

a two-wheel bicycle that he can handle the three wheeler, but reasoning from knowledge of another child's three-wheel-ability structure to a two-wheel-ability structure is more tenuous. A second aspect of structure, besides this directional predictability, is the integrative one. From this point of view the higher level structure integrates the lower level structures into its organization. Or put alternatively, the lower level structures become component and interactive parts of the higher level structure. Thus the higher level cognitive structure--knowledge of calculus - involves the integration and interaction among lower level structures - knowledge of algebra, knowledge of plane geometry, knowledge of analytic geometry and so on. Let us apply these two criteria of hierarchical organization to the concepts of factor, learning set, and schema-operation. I believe such application has definite relevance to enrichment procedures.

Consider the relationship between group factors and a general factor. Humphreys (6) in a recent article and Cattell (1) in an article that appeared a number of years ago have pointed out consistencies in the British and American factor analysis findings. There is agreement with respect to the existence of two kinds of factors, the general intellective factor and the group factors, such as verbal comprehension, space, and number facility. The disagreements are statistical rather than substantive. The British school pulls out a large general factor at the same time as it uncovers the group factors, whereas the American investigators, who in the main follow Thurstone's methods, pull out the group factors first and then uncover the general factor by performing a second factor analysis on the group factors.

But let's see what this has to do with organisational hierarchy of cognitive structures. From a predictive viewpoint, the general factor is a higher order structure than the group factor. Thus with knowledge that an individual is strong on the general factor we would predict that he would do well in new verbal, numerical, or spatial situations. Prediction from a lower order factor to the more general is more tenuous. Because a person has a high verbal facility, it becomes dangerous to predict to his general competence, and dangerous to infer that his numerical and his spatial and his memory abilities are high.

From the integrative point of view, the question of whether a general factor is a higher order structure than a group factor poses an interesting problem. A very stimulating article by Ferguson (2) some years ago offers a theory that says "yes". It is his belief that the general factor results from the reciprocal influences among the group factors. Thus the development of verbal ability may transfer to the development of spatial ability and the development of spatial ability would have a reciprocal influence (I hate to use the word counter-transference) on the development of verbal ability. The general ability would therefore evolve from the mutual facilitation of component lower order structures. Ferguson's theory has the great merit of aligning the development of intelligence with the principles of learning since a key feature of his hypothesis is the reciprocal transfer

effects of developing primary abilities or group factors. The question immediately arises as to the nature of the experiences that would be productive of such inter-facilitative transfer effects. Put otherwise, what kind of learning sets would you have to establish in a group of subjects in order to get this general factor?

I think the experience relevant to a factor cutting through verbal and perceptual abilities involves adaptation to perceptual situations where verbal cues are helpful. One great class of such situations arises when verbal labels aid in the differentiation of perceptually similar objects. I do not mean vocabulary building, nor do I mean sheer exposure to new sights and sounds. What I do mean is exposure to situations where a parent or teacher points out the discriminating features and supplies differential labels for situations which are otherwise perceptually similar.

The kind of verbal-perceptual discriminations I mean are those between mackintosh and delicious apples, between maples and elms, between dimes and nickels, between alligators and crocodiles, between the appearance of twinkling stars and non-twinkling planets, between eagles and owls, between circles and ellipses, between Buicks and Pontiacs and so on. Again using a hypothetical experiment of a type we have used before, if 100 children were given a battery of perceptual and verbal tests, then the appearance of a general factor underlying both perceptual and verbal factors might be traceable to differential learning experiences of the type described above. Such life history data would be extremely difficult to collect, and again an enrichment program would be a logical place where the effectiveness of such perceptual-linguistic experiences might be ascertained. It may be also that the more differentiated language of the middle-class parent coupled with the more variegated perceptual experience for his child combined with the stronger teaching drive of the parent produce far more of these perceptual-linguistic experiences than in the case of the lower-class child. This differential experience would in turn be reflected in intelligence test scores. Nor would the situation be relieved at all by those culture-free tests which rely mainly on perceptual material, since the middle-class child has had a background of verbal facilitation which would be reflected in differential scores even on non-verbal material. In this connection it is interesting to note the relatively low correlation between verbal and performance IQ's obtained by Dr. Cynthia Deutsch at the Institute among a group of reading retarded children. Assuming a background in which there is little cross-transfer between linguistic and perceptual habits, one would predict the relative isolation of these two systems, which would be reflected in a lower correlation between the verbal and performance measures.

The transitions between sensory-motor schemata and operations in Piaget's system also illustrate this idea of the hierarchical organization among cognitive structures. From a predictive point of view, Piaget's arrangement of cognitive structures forms a massive Guttman scale with formal operations as the highest order structure, concrete operations next lower down, and intuitive regulations, the pre-conceptual phase, and the sensorimotor stages following in downward progression. This means that if you know that the individual is at a higher level, say at the stage of

formal operations, then he should be able to handle problems at all lower levels, but that the reverse reasoning is more risky. Thus, if the individual is at the stage of concrete operations then there is no guarantee that he can handle problems at the phase of formal operations. From the integrative point of view, Piaget's writings continually reflect the role that lower order structures play in the formation of higher order structures. For example, in discussing the development of primitive habits from elementary reflexes, Piaget points out the hierarchical arrangement of the two structures--the lower order reflex and the higher order habit.

"But it is important to realize that the extension of the reflex-schemata, through the incorporation of a new element, involves by this very fact the formation of a schema of a higher order, (a genuine habit), which then integrates the lower schema within inself." (8, p. 100).

Perhaps we can illustrate this whole integrative process on a broader scale by an example. Suppose we were to ask a 12-year-old this question--John is bigger than Jim but smaller than George, who is the smallest one? Suppose too that he responds correctly that Jim is the smallest and gives a carefully reasoned explanation of his answer. How are we to understand this?

From Piaget's viewpoint, he responds correctly because he has certain accommodative intellectual structures which are capable of assimilating this bit of environment represented by the problem and handling it. If we were able to look back upon the relevant experience in this child's life which determined the formation of such structures, we might observe something like this: Between the ages of birth and two years old the child has had a good deal of sensori-motor experience with big and small objects. The large block didn't go into the small window of the toy house but the small one did. The big book on the floor was hard to shove; the little book responded easily. These sensori-motor experiences might have been followed in the pre-conceptual phase at around three years with linguistic attempts at representation of big and little.

These attempts, according to Piaget, are somewhere between idiosyncratic and socialized representation. Thus the child might apply the term "big" to glassy objects or black objects or square-shaped objects because of an association with the big, black, square bookcase with the mirror on it in his home.

During the intuitive stage, lasting roughly from about four to seven years, the child may gain a more consistent and socialized idea of the concepts of big and little and of their socially agreed-upon verbal tags. Thus at five years, he is able to separate upon request the "small cookies" from the "big cookies" when he is given an assortment in two sizes. However, he may have difficulty rank ordering a set of cookies from the smallest to the largest. It is difficult for him to grasp that a given object may be large relative to one and small relative to another, or that a given thing may be in two or more categories simultaneously. Transitivity, the idea that if A is greater than B and B is greater than C, then A is greater than C, is beyond his ken.

Four years later, when the child is about nine or ten, and in the phase of concrete operations, the ordering of objects according to size poses little difficulty. Thus, if a series of dolls of ascending size are laid before him, he has little difficulty matching an ascending series of toy canes, or even reversing the seriation upon request so that the largest doll ends up with the smallest cane, the next largest doll with the next smallest cane and so on. In this phase of concrete operations, the child can deal with problems of seriation and transitivity when working with concrete materials - dolls, canes, toys, squares, etc. However, he cannot handle the same type of problem presented "mentally" as in the illustration we began -- John is bigger than Jim but smaller than George. Who is the smallest one? This ability to deal with propositions or symbolic representations of the concrete reality develops around adolescence and is known as the stage of formal operations.

The integration of these various structures into a hierarchy I think, is a little clearer now. But let's pinpoint it. Sensory motor schemata become integrated with primitive verbal representations to form pre-concepts. Pre-concepts become sharpened into the more socialized individual concepts. Individual concepts fuse and interrelate to determine concrete operations. The concrete operations become less concrete, more divorced from particular spatial or perceptual material, and become formal operations. Two points should be made in connection with this picture of mental development. The first is the obvious point that progress from stage to stage depends upon the interaction of neural and experiential factors. The particular mechanisms at work, what kinds of experiential factors in combination with what kinds of neural stuff are most effective in accelerating or retarding cognitive growth is a grand mystery, and urgently needs some good research. Secondly, if we turn to the experiential factors, a fruitful activity I think, is the exploration of learning sets within a particular stage as a preparation for movement to a higher stage. As an example, let us look at what is the most pertinent stage from the viewpoint of this conference, i.e., the intuitive phase spanning the age range from about four to seven. At this stage, children have some facility in using individual concepts, but have difficulty dealing with the arrangement of concepts in hierarchies. Take the superordinate category, children, and two subordinate categories, boys and girls. A five-year old has no difficulty handling each of these concepts separately. He can differentiate children from grown-ups, or boys from girls. But he does have great difficulty seeing the relationship between the subordinate and superordinate classes. Thus he has difficulty recognizing that there are more children in his kindergarten room than there are girls. He has difficulty recognizing that there is more fruit on the table than there are apples, or for that matter that there is more food on the table than fruit. A good part of the difficulty, according to Piaget, is that the child centers his attention on one aspect or property of an object at a time. Thus he can look at that thing on the table and see it or think of it as an apple, or he can see it as a fruit, but he cannot see it as <u>both</u> an apple and a fruit at the same time. It is this latter ability to adopt multiple and simultaneous categorizations that are at the heart of his conceptual difficulty. If this is so, then the kind of sorting and classifying experiences the child should have in an enrichment program should prepare him for this difficult task of multiple categorization. Perhaps we should begin to develop in him a learning set that this thing on the table is not just an apple, but also a fruit, also something red, also something round and so on, depending on context.

More concretely, if we wish him to categorize this thing as an apple, have him group this thing with other apples and have him separate the apples from a group of non-apples, say a group of bananas. If we then wish him to categorize this thing as a fruit, have him group this thing with other fruit and have him separate the fruit from the non-fruit, say from the pieces of bread. Analagous programs could then be followed for the alternative categorization of this thing as "something red" or "something round" and so on. The possibility might be explored of adapting such procedures for (a) the learning of self-concepts, that this same "me" can be a boy, and a brother, and a son, and a monitor, or for (b) the learning of problem solving sets, that this same thing can be a screwdriver in this context, but a lever in another context and a stick in a third setting.

Finally, let us turn briefly to the hierarchical organization of learning sets. From a predictive standpoint, Harlow's learning curves show that you can predict that a subject with a learning set based on 300 problems will perform at least as efficiently on new problems as the subject who has solved 50 problems, but the reverse reasoning is on shakier ground. And in this sense one can speak of higher and lower order learning sets. From an integrative viewpoint, what lower order structures a higher order learning set combines is an interesting question. Perhaps, as Harlow theorizes, a developed learning set represents a fusion of adaptive inhibitory tendencies so that irrelevant perseverations and distractions do not interfere when a new problem is faced.

Again, from an integrative standpoint, I would suggest that higher order learning sets involve exposure to higher order learning situations, i.e., those that require and reward the use of several lower order sets. Perhaps it is through the learning of such integrations that the higher order set is developed. Thus the development of the learning set to make multiple categorizations of the same object may involve not only (a) the development of lower order single-categorization sets (this thing is an apple, this thing is a fruit, etc.), but also (b) exposure to a series of situations whose common element is that they require the fusion of these ideas. Situations requiring the quantitative comparison of objects classed as both apples and fruit would comprise one such class, but many more of such situational classes might be required for really effective learning.

By way of summary -- this has been an attempt to relate consistency of inter-situational experience to a consistency in inter-situational performance. A factor, a learning set, a schema, or an operation, all involve competence with respect to a class of diverse situations. But if these situations form a class, they must have some features in common. If it means anything, intelligence must mean sensitivity to these common features. Such sensitivity, I think, can be fostered through the continual learning of these common features presented in diverse settings. Such sensitivities should be expressed in tests or transferred to life achievements to the degree that these sample the situational contexts in which learning has taken place, and demand knowledge of the simple or complex common features that have been learned.

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